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Lake James, Steuben County, Indiana

Pacific Northwest Environmental Res. Lab.

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March 1976

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16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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NATIONAL EUTROPHICATION SURVEY

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REPORT
ON
LAKE JAMES
STEUBEN COUNTY
INDIANA
EPA REGION V
WORKING PAPER No. 331

WITH THE COOPERATION OF THE
INDIANA STATE BOARD OF HEALTH
AND THE
INDIANA NATIONAL GUARD
MARCH, 1976

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to fresh water lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning {§303(c)}, water quality criteria/standards review {§303(c)}, clean lakes {§314(a,b)}, and water quality monitoring {§106 and §305(b)} activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's fresh water lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the Indiana State Board of Health for professional involvement, to the Indiana National Guard for conducting the tributary sampling phase of the Survey, and to those Indiana wastewater treatment plant operators who provided effluent samples and flow data.

The staff of the Division of Water Pollution Control, Indiana State Board of Health, provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

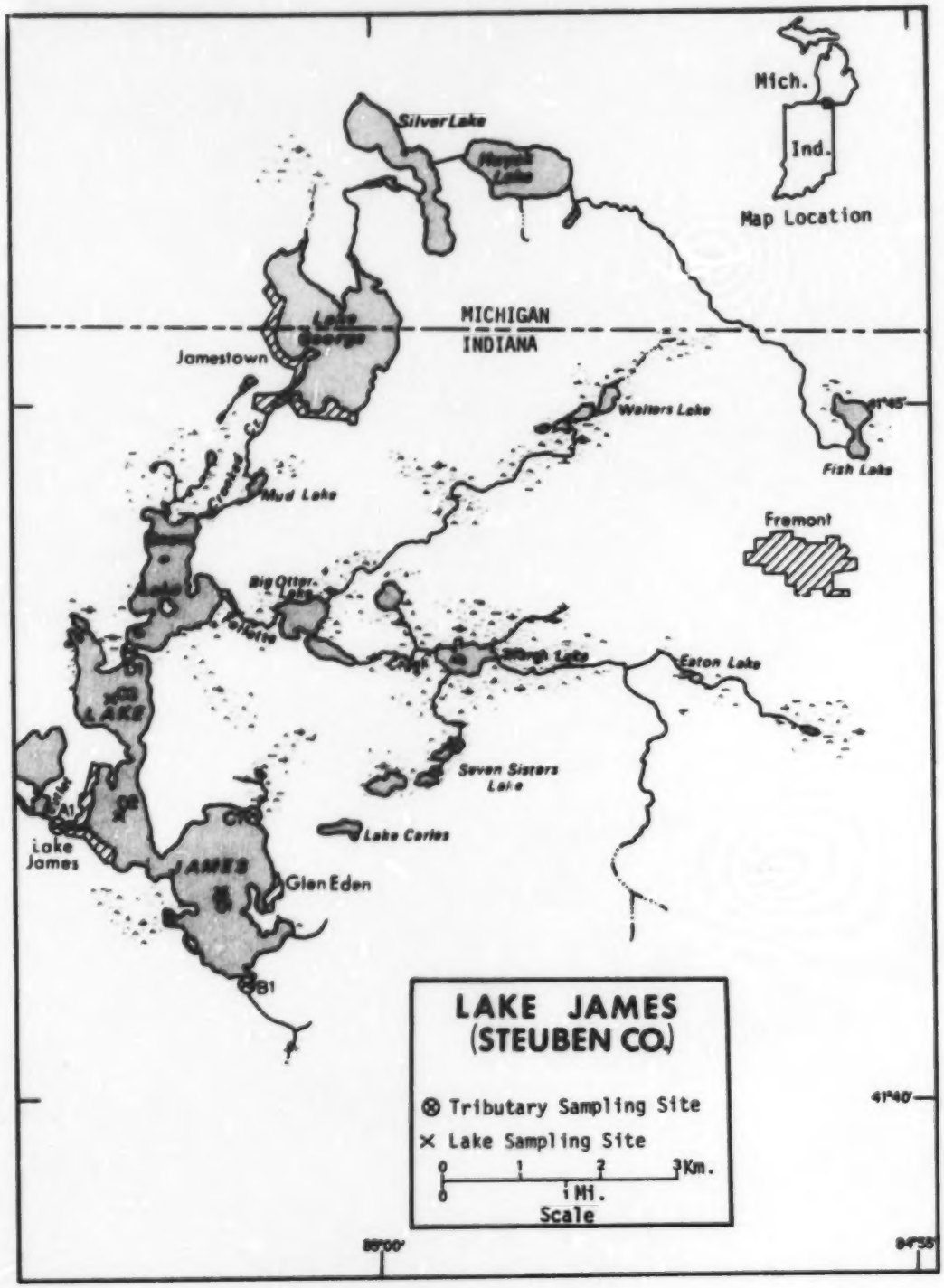
Major General Alfred F. Ahner, Adjutant General of Indiana, and Project Officers Lt. Colonel Charles B. Roberts (Retired) and Colonel Robert L. Sharp, who directed the volunteer efforts of the Indiana National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF INDIANA

LAKE NAME	COUNTY
Bass	Starke
Cataract	Owen, Putnam
Crooked	Steuben
Dallas	LaGrange
Geist	Hamilton, Marion
Hamilton	Steuben
Hovey	Posey
James	Kosciusko
James	Steuben
Long	Steuben
Marsh	Steuben
Mississinewa	Grant, Miami, Wabash
Maxinkuckee	Marshall
Monroe	Brown, Monroe
Morse	Hamilton
Olin	LaGrange
Oliver	LaGrange
Pigeon	Steuben
Sylvan	Noble
Tippecanoe	Kosciusko
Versailles	Ripley
Wawassee	Kosciusko
Webster	Kosciusko
Westler	LaGrange
Whitewater	Union
Winona	Kosciusko
Witmer	LaGrange


Mich.
Ind.
Map Location
Silver Lake
MICHIGAN
INDIANA
Jamestown
Walters Lake
Fish Lake
Mud Lake
Fremont
Big Otter Lake
Eaton Lake
Seven Sisters Lake
Lake Carlos
Lake James
Glen Eden
A1
B1
LAKE JAMES
(STEUBEN CO.)
⊗ Tributary Sampling Site
× Lake Sampling Site
0 1 2 3Km.
0 1Mi.
Scale
41°40'
85°00'
84°55'

LAKE JAMES

STORET NO. 1853

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that Lake James is mesotrophic. Of the 27 Indiana lakes sampled in 1973, it ranked third in overall trophic quality when compared using a combination of six parameters*. Three lakes had less median total phosphorus, four had less and three had the same median dissolved phosphorus, two had less median inorganic nitrogen, one had less mean chlorophyll a, and none of the others had greater mean Secchi disc transparency.

Survey limnologists noted moderate algal blooms in August, and submerged and emergent macrophytes were observed in shallows along the shorelines. Hypolimnetic depletion of dissolved oxygen occurred at all three sampling stations in August and October.

B. Rate-Limiting Nutrient:

The algal assay results indicate that Lake James was limited by phosphorus at the time the sample was collected (05/02/73). The lake data indicate phosphorus limitation in October as well but probable nitrogen limitation in August.

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* See Appendix A.

C. Nutrient Controllability:

1. Point sources--No known municipal or industrial point sources impacted Lake James during the sampling year. Septic tanks serving lakeshore residences contributed an estimated 6.1% of the total input to the lake, but a shoreline survey would be needed to determine the significance of these sources.

The present phosphorus loading of 0.34 $g/m^2/yr$ is less than that proposed by Vollenweider (Vollenweider and Dillon, 1974) as a eutrophic loading (see page 11). Future developments should be carefully evaluated in regard to phosphorus contributions to the lake. If the existing loading is not increased, the trophic condition of the lake should persist.

2. Non-point sources--Non-point sources accounted for 94.0% of the annual total phosphorus input to the lake. Unnamed Creek D-1 contributed 76.0%, and the remaining two tributaries collectively contributed 6.7%. Ungaged tributaries were estimated to have contributed 6.0% of the total.

The phosphorus export rates of the Lake James tributaries were relatively low during the sampling year (see page 10).

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS†

A. Lake Morphometry††:

1. Surface area: 4.18 kilometers^2.
2. Mean depth: 7.3 meters.
3. Maximum depth: 26.2 meters.
4. Volume: 30.514 x 10^6 m^3.
5. Mean hydraulic retention time: 312 days.

B. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries -

Name	Drainage area (km^2)*	Mean flow (m^3/sec)*
Unnamed Creek B-1	4.1	0.04
Unnamed Creek C-1	3.9	0.04
Unnamed Creek D-1	104.1	0.98
Minor tributaries & immediate drainage -	7.5	0.07
Totals	119.6	1.13

2. Outlet -

Unnamed Creek A-1	123.8**	1.13

C. Precipitation***:

1. Year of sampling: 111.6 centimeters.
2. Mean annual: 91.3 centimeters.

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† Table of metric conversions--Appendix B.
†† Winters, 1975.
* For limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".
** Includes area of lake; outflow adjusted to equal sum of inflows.
*** See Working Paper No. 175.

III. LAKE WATER QUALITY SUMMARY

Lake James was sampled three times during the open-water season of 1973 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from a number of depths at three stations on the lake (see map, page v). During each visit, a single depth-integrated (4.6 m to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the first visit, a single 18.9-liter depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll *a* analysis. The maximum depths sampled were 16.8 meters at station 1, 19.8 meters at station 2, and 24.7 meters at station 3.

The sampling results are presented in full in Appendix D and are summarized in the following table.

A. SUMMARY OF PHYSICAL AND CHEMICAL CHARACTERISTICS FOR LAKE JAMES
STORET CODE 1853

PARAMETER	1ST SAMPLING (5/ 2/73) 3 SITES RANGE	MEAN	MEDIAN	2ND SAMPLING (8/ 4/73) 3 SITES RANGE	MEAN	MEDIAN	3RD SAMPLING (10/15/73) 3 SITES RANGE	MEAN	MEDIAN
TEMP (C)	8.4 - 12.9	11.9	12.7	8.0 - 25.8	16.8	14.0	6.5 - 18.6	13.3	13.0
DISS OXY (MG/L)	7.7 - 10.6	10.0	10.4	0.0 - 8.8	4.6	4.5	0.0 - 9.0	3.0	0.2
CNDCTVY (MCROMO)	480. - 500.	496.	498.	330. - 456.	392.	375.	336. - 390.	369.	374.
PH (STAND UNITS)	8.0 - 8.4	8.2	8.3	7.3 - 8.5	7.8	7.6	7.3 - 8.5	7.8	7.6
TOT ALK (MG/L)	180. - 186.	183.	182.	150. - 195.	174.	176.	153. - 197.	173.	178.
TOT P (MG/L)	0.010 - 0.107	0.021	0.015	0.013 - 0.219	0.040	0.018	0.008 - 0.478	0.047	0.014
ORTHO P (MG/L)	0.002 - 0.089	0.009	0.004	0.004 - 0.217	0.028	0.007	0.003 - 0.310	0.030	0.007
NO2+NO3 (MG/L)	0.110 - 0.140	0.127	0.130	0.040 - 0.400	0.102	0.060	0.020 - 0.100	0.051	0.050
AMMONIA (MG/L)	0.070 - 0.320	0.097	0.080	0.040 - 1.220	0.250	0.070	0.050 - 1.700	0.365	0.105
KJEL N (MG/L)	0.500 - 0.900	0.644	0.600	0.400 - 1.800	0.905	0.800	0.500 - 4.600	1.083	0.750
INORG N (MG/L)	0.190 - 0.430	0.224	0.210	0.080 - 1.410	0.352	0.140	0.090 - 1.760	0.416	0.145
TOTAL N (MG/L)	0.620 - 1.010	0.771	0.730	0.540 - 1.890	1.007	0.875	0.540 - 4.660	1.134	0.880
CHLRPYL A (UG/L)	4.9 - 6.5	5.6	5.3	4.6 - 4.7	4.6	4.6	3.2 - 5.9	4.4	4.8
SECCHI (METERS)	4.4 - 5.2	4.7	4.6	2.5 - 2.7	2.7	2.7	3.7 - 4.0	3.9	4.0

B. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
05/02/73	1. *Asterionella sp.*	496
	2. *Schroederia sp.*	481
	3. Flagellates	341
	4. *Cryptomonas sp.*	186
	5. *Fragilaria sp.*	155
	Other genera	233
	Total	1,892
08/04/73	1. Flagellates	400
	2. *Microcystis sp.*	218
	3. *Dinobryon sp.*	182
	4. *Merismopedia sp.*	163
	5. *Lyngbya sp.*	127
	Other genera	381
	Total	1,471
10/15/73	1. *Dinobryon sp.*	337
	2. Flagellates	258
	3. Pennate diatoms	119
	4. *Cryptomonas sp.*	99
	5. *Coelosphaerium sp.*	99
	Other genera	219
	Total	1,131

2. Chlorophyll *a* -

Sampling Date	Station Number	Chlorophyll *a* (µg/l)
05/02/73	1	6.5
	2	5.3
	3	4.9
08/04/73	1	4.7
	2	4.6
	3	4.6
10/15/73	1	3.2
	2	4.0
	3	5.9

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.008	0.226	0.1
0.050 P	0.058	0.226	5.3
0.050 P + 1.0 N	0.058	1.226	14.2
1.0 N	0.008	1.226	0.1

2. Discussion -

The control yield of the assay alga, Selenastrum capricornutum, indicates that the potential primary productivity of Lake James was low at the time the sample was collected (05/02/73). The results also show the lake was phosphorus limited at that time. Note the significant increase in yield when the level of orthophosphorus was increased but the lack of change in yield when only nitrogen was added.

The lake data indicate phosphorus limitation in October as well (the mean inorganic nitrogen/orthophosphorus ratio was 14/1) but probable nitrogen limitation in August (the mean N/P ratio was 13/1).

IV. NUTRIENT LOADINGS
(See Appendix E for data)

For the determination of nutrient loadings, the Indiana National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), except for the high runoff month of March when two samples were collected. Sampling was begun in June, 1973, and was completed in May, 1974.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the Indiana District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were determined by using a modification of a U.S. Geological Survey computer program for calculating stream loadings*.

Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the means of the nutrient loads, in kg/km^2/year, at stations B-1, C-1, and D-1 and multiplying the means by the ZZ area in km^2.

The estimated phosphorus load from septic tanks was reduced by 50% to adjust for a ban on phosphate detergents which has been in effect in Indiana since 1972.

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* See Working Paper No. 175.

A. Waste Sources:

1. Known municipal - None

2. Known industrial - None

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/ yr	% of total
a. Tributaries (non-point load) -		
Unnamed Creek B-1	30	2.1
Unnamed Creek C-1	65	4.6
Unnamed Creek D-1	1,080	76.0
b. Minor tributaries & immediate drainage (non-point load) -	85	6.0
c. Known municipal STP's - None	-	-
d. Septic tanks* -	85	6.0
e. Known industrial - None	-	-
f. Direct precipitation** -	75	5.3
Total	1,420	100.0

2. Outputs -

Lake outlet - Unnamed Creek A-1 590

3. Net annual P accumulation - 830 kg.

* Estimate based on 565 lakeshore residences, two camps, and one park; see Working Paper No. 175.
** See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (non-point load) -		
Unnamed Creek B-1	2,005	3.6
Unnamed Creek C-1	1,250	2.2
Unnamed Creek D-1	39,260	69.9
b. Minor tributaries & immediate drainage (non-point load) -	2,965	5.3
c. Known municipal STP's - None	-	-
d. Septic tanks* -	6,195	11.0
e. Known industrial - None	-	-
f. Direct precipitation** -	4,515	8.0
Total	56,190	100.0

2. Outputs -

Lake outlet - Unnamed Creek A-1 30,490

3. Net annual N accumulation - 25,700 kg.

D. Mean Annual Non-point Nutrient Export by Subdrainage Area:

Tributary	kg P/km²/yr	kg N/km²/yr
Unnamed Creek B-1	7	489
Unnamed Creek C-1	17	321
Unnamed Creek D-1	10	377

* Estimate based on 565 lakeshore residences, two camps, and one park; see Working Paper No. 175.
** See Working Paper No. 175.

E. Yearly Loads:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
grams/m^2/yr	0.34	0.20	13.4	6.1

Vollenweider phosphorus loadings ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of Lake James:	
"Dangerous" (eutrophic loading)	0.56
"Permissible" (oligotrophic loading)	0.28

V. LITERATURE REVIEWED

Vollenweider, R. A., and P. J. Dillon, 1974. The application of the phosphorus loading concept to eutrophication research. Natl. Res. Council of Canada Publ. No. 13690, Canada Centre for Inland Waters, Burlington, Ontario.

Winters, John, 1975. Personal communication (lake morphometry). IN Div. of Water Poll. Contr., Indianapolis.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P
1805	CATARACT LAKE	0.059	1.600	466.667	10.744	15.000	0.013
1811	GEIST RESERVOIR	0.074	1.080	472.500	45.950	11.600	0.009
1817	JAMES LAKE	0.024	1.030	434.000	11.533	15.000	0.004
1827	MISSISSINEWA RESERVOIR	0.107	2.400	473.444	15.778	15.000	0.029
1828	MONROE RESERVOIR	0.025	0.325	438.623	6.947	15.000	0.007
1829	MORSE RESERVOIR	0.084	3.325	473.222	56.167	15.000	0.009
1836	WAWASEE LAKE	0.012	0.210	364.500	5.000	14.600	0.003
1837	WEBSTER LAKE	0.025	0.790	431.000	11.500	15.000	0.005
1839	WHITEWATER LAKE	0.084	1.620	470.167	33.083	15.000	0.012
1840	WINONA LAKE	0.035	1.250	444.667	11.211	15.000	0.011
1841	WESTLER LAKE	0.035	0.860	427.125	10.712	15.000	0.013
1842	WITMER LAKE	0.035	0.980	440.333	11.917	15.000	0.011
1843	LAKE MAXINKUCKEE	0.020	0.220	488.480	5.483	15.000	0.003
1844	TIPPECANOE LAKE	0.019	0.195	391.500	6.050	15.000	0.005
1845	DALLAS LAKE	0.029	0.830	413.333	10.067	15.000	0.014
1846	OLIN LAKE	0.012	1.460	403.333	4.867	14.900	0.003
1847	OLIVER LAKE	0.009	0.920	392.000	3.767	14.800	0.004
1848	SYLVAN LAKE	0.170	0.130	469.833	47.480	14.800	0.017
1849	HOVEY LAKE	0.062	1.050	489.333	84.267	7.000	0.024
1850	VERSAILLES LAKE	0.139	1.090	482.000	25.070	14.500	0.019
1851	RASS LAKE	0.040	0.250	471.375	29.367	7.000	0.012
1852	CROOKED LAKE	0.019	0.120	410.111	5.578	15.000	0.005
1853	LAKE JAMES	0.016	0.190	352.444	4.856	15.000	0.005
1854	LONG LAKE	0.204	1.920	442.667	16.100	15.000	0.150
1855	PIGEON LAKE	0.058	1.945	442.667	11.900	15.000	0.015
1856	MARSH LAKE	0.093	0.270	451.333	34.467	15.000	0.055
1857	HAMILTON LAKE	0.033	0.720	413.167	17.450	15.000	0.010

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P	INDEX NU
1805	CATARACT LAKE	37 (9)	15 (4)	31 (8)	62 (16)	35 (0)	37 (9)	217
1811	GEIST RESERVOIR	27 (7)	35 (9)	15 (4)	12 (3)	92 (24)	62 (16)	243
1817	JAMES LAKE	73 (19)	42 (11)	58 (15)	50 (13)	35 (0)	65 (17)	323
1827	MISSISSINEWA RESERVOIR	12 (3)	4 (1)	8 (2)	38 (10)	35 (0)	8 (2)	105
1828	MONROE RESERVOIR	67 (17)	69 (18)	54 (14)	73 (19)	35 (0)	69 (18)	367
1829	MORSE RESERVOIR	23 (6)	0 (0)	12 (3)	4 (1)	35 (0)	58 (15)	132
1836	WAWASEE LAKE	94 (24)	85 (22)	96 (25)	88 (23)	65 (22)	98 (25)	546
1837	WEBSTER LAKE	67 (17)	62 (16)	62 (16)	54 (14)	35 (0)	81 (21)	361
1839	WHITEWATER LAKE	19 (5)	19 (5)	23 (6)	19 (5)	35 (0)	42 (11)	157
1840	WINONA LAKE	50 (12)	27 (7)	38 (10)	58 (15)	35 (0)	52 (13)	260
1841	WESTLER LAKE	50 (12)	54 (14)	65 (17)	65 (17)	35 (0)	37 (9)	306
1842	WITMER LAKE	50 (12)	50 (13)	50 (13)	42 (11)	35 (0)	52 (13)	279
1843	LAKE MAXINKUCKEE	77 (20)	81 (21)	65 (22)	85 (22)	35 (0)	98 (25)	461
1844	TIPPECANOE LAKE	85 (22)	88 (23)	92 (24)	77 (20)	35 (0)	85 (22)	462
1845	DALLAS LAKE	62 (16)	58 (15)	69 (18)	69 (18)	35 (0)	31 (8)	324
1846	OLIN LAKE	94 (24)	23 (6)	81 (21)	92 (24)	73 (19)	92 (24)	455
1847	OLIVER LAKE	100 (26)	46 (12)	88 (23)	100 (26)	79 (20)	88 (23)	501
1848	SYLVAN LAKE	4 (1)	96 (25)	27 (7)	8 (2)	79 (20)	23 (6)	237
1849	HOVEY LAKE	31 (8)	38 (10)	0 (0)	0 (0)	96 (25)	12 (3)	177
1850	VERSAILLES LAKE	8 (2)	31 (8)	4 (1)	27 (7)	88 (23)	15 (4)	173
1851	BASS LAKE	42 (11)	77 (20)	19 (5)	23 (6)	100 (26)	46 (12)	307
1852	CROOKED LAKE	81 (21)	100 (26)	77 (20)	81 (21)	35 (0)	75 (19)	449
1853	LAKE JAMES	88 (23)	92 (24)	100 (26)	96 (25)	35 (0)	75 (19)	486
1854	LONG LAKE	0 (0)	12 (3)	44 (11)	35 (9)	35 (0)	0 (0)	126
1855	PIGEON LAKE	37 (9)	8 (2)	44 (11)	46 (12)	35 (0)	27 (7)	197
1856	MAHSH LAKE	15 (4)	73 (19)	35 (9)	15 (4)	35 (0)	4 (1)	177
1857	HAMILTON LAKE	50 (15)	65 (17)	73 (19)	31 (8)	35 (0)	19 (5)	281

LAKES RANKED BY INDEX NOS.

RANK	LAKE CODE	LAKE NAME	INDEX NO
1	1836	WAWASEE LAKE	546
2	1847	OLIVER LAKE	501
3	1853	LAKE JAMES	486
4	1844	TIPPECANOE LAKE	462
5	1843	LAKE MAXINKUCKEE	461
6	1846	OLIN LAKE	455
7	1852	CROOKED LAKE	449
8	1828	MONROE RESERVOIR	367
9	1837	WEBSTER LAKE	361
10	1845	DALLAS LAKE	324
11	1817	JAMES LAKE	323
12	1851	BASS LAKE	307
13	1841	WESTLER LAKE	306
14	1857	HAMILTON LAKE	281
15	1842	WITHER LAKE	279
16	1840	WINONA LAKE	260
17	1811	GEIST RESERVOIR	243
18	1848	SYLVAN LAKE	237
19	1885	CATARACT LAKE	217
20	1855	PIGEON LAKE	197
21	1856	MARSH LAKE	177
22	1849	HOVEY LAKE	177
23	1850	VERSAILLES LAKE	173
24	1839	WHITEWATER LAKE	157
25	1829	HORSE RESERVOIR	132
26	1854	LONG LAKE	126
27	1827	MISSISSINEWA RESERVOIR	105

APPENDIX B

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR INDIANA 03/29/76

LAKE CODE 1853 LAKE JAMES

TOTAL DRAINAGE AREA OF LAKE(SQ KM) 123.8

TRIBUTARY	SUB-DRAINAGE AREA(SQ KM)	NORMALIZED FLOWS(CMS) JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
1853A1	123.8	1.54	1.79	2.58	2.36	1.53	1.16	0.71	0.27	0.25	0.27	0.61	1.10	1.17
1853B1	4.1	0.045	0.059	0.088	0.079	0.051	0.048	0.023	0.006	0.007	0.007	0.020	0.040	0.039
1853C1	3.9	0.042	0.054	0.082	0.074	0.048	0.037	0.021	0.006	0.006	0.006	0.019	0.037	0.036
1853D1	104.1	1.29	1.50	2.11	1.98	1.29	0.97	0.59	0.22	0.20	0.22	0.51	0.93	0.98
1853Z2	7.5	0.085	0.108	0.156	0.144	0.091	0.071	0.042	0.012	0.012	0.012	0.037	0.071	0.070

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 123.8
SUM OF SUB-DRAINAGE AREAS = 119.7

TOTAL FLOW IN = 13.56
TOTAL FLOW OUT = 14.08

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
1853A1	6	73	1.968	9	2.528				
	7	73	1.515	15	1.926				
	8	73	1.082	12	1.218				
	9	73	0.385	12	0.396				
	10	73	0.391	14	0.481				
	11	73	0.445	11	0.311				
	12	73	1.113	8	1.848				
	1	74	2.192	6	1.614				
	2	74	2.676	10	2.435	24	3.058		
	3	74	3.823	10	5.885	26	2.407		
	4	74	2.532	9	3.143				
	5	74	2.832	5	1.472				
1853B1	6	73	0.065	9	0.085				
	7	73	0.048	15	0.062				
	8	73	0.033	12	0.034				
	9	73	0.014	12	0.015				
	10	73	0.013	14	0.017				
	11	73	0.016	11	0.011				
	12	73	0.037	8	0.034				
	1	74	0.072	6	0.048				
	2	74	0.085	10	0.071	24	0.093		
	3	74	0.103	10	0.156	26	0.065		
	4	74	0.077	9	0.074				
	5	74	0.078	5	0.048				

TRIBUTARY FLOW INFORMATION FOR INDIANA 03/29/76

LAKE CODE 1853 LAKE JAMES

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
1853C1	6	73	0.061	9	0.079				
	7	73	0.045	15	0.057				
	8	73	0.031	12	0.034				
	9	73	0.013	12	0.014				
	10	73	0.012	14	0.016				
	11	73	0.015	11	0.010				
	12	73	0.035	8	0.031				
	1	74	0.068	6	0.045				
	2	74	0.079	10	0.065	24	0.088		
	3	74	0.096	10	0.147	26	0.062		
	4	74	0.072	9	0.071				
	5	74	0.073	5	0.037				
1853D1	6	73	1.637	9	1.841				
	7	73	1.150	15	0.850				
	8	73	0.742	12	0.765				
	9	73	0.371	12	0.425				
	10	73	0.343	14	0.453				
	11	73	0.433	11	0.275				
	12	73	0.946	8	0.850				
	1	74	1.790	6	1.184				
	2	74	1.999	10	1.444	24	2.152		
	3	74	1.943	10	2.265	26	1.246		
	4	74	1.730	9	1.699				
	5	74	1.526	5	0.736				
1853ZZ	6	73	0.119	9	0.153				
	7	73	0.092	15	0.116				
	8	73	0.066	12	0.074				
	9	73	0.023	12	0.024				
	10	73	0.024	14	0.028				
	11	73	0.027	11	0.019				
	12	73	0.067	8	0.062				
	1	74	0.133	6	0.096				
	2	74	0.162	10	0.147	24	0.187		
	3	74	0.232	10	0.340	26	0.147		
	4	74	0.153	9	0.190				
	5	74	0.172	5	0.091				

APPENDIX D

PHYSICAL and CHEMICAL DATA

STORET RETRIEVAL DATE 76/03/30

105301
41 41 34.0 085 01 28.0 3
LAKE JAMES
18151 INDIANA

083291

11EPALES 2111202
0055 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT K JEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
73/05/02	13 50	0000	12.7		180	495	8.30	182	0.080	0.600	0.130	0.002
	13 50	0006	12.6	10.4		495	8.30	181	0.070	0.500	0.120	0.004
	13 50	0015	12.7	10.4		490	8.40	182	0.070	0.500	0.120	0.003
	13 50	0025	12.6	10.3		495	8.30	181	0.070	0.600	0.120	0.003
	13 50	0037	11.8	10.5		500	8.30	182	0.080	0.600	0.120	0.005
	13 50	0051	9.4	9.1		495	8.20	182	0.110	0.600	0.130	0.002
73/08/04	14 35	0000	25.3	8.7	108	448	8.40	155	0.050	1.000	0.050	0.004
	14 35	0005	25.0	8.7		443	8.50	153	0.070	0.800	0.040	0.005
	14 35	0010	24.8			438						
	14 35	0015	24.3	8.6		433	8.00	150	0.060	0.700	0.060	0.004
	14 35	0020	20.0	2.4		415	7.70	172	0.040	0.800	0.050	0.004
	14 35	0025	15.0	7.3		388	7.40	179	0.100	0.900	0.090	0.006
	14 35	0030	13.5			378						
	14 35	0035	12.9			369						
	14 35	0040	12.6	9.0		369	7.50	185	0.360	1.200	0.040	0.007
	14 35	0045	12.4			367						
	14 35	0050	12.0			370						
	14 35	0055	11.7	0.0		370	7.40	191	0.900	1.000	0.000	0.027
73/10/15	14 00	0000	17.5	8.4	144	381	8.30	157	0.040	0.700	0.050	0.011
	14 00	0025	17.4	8.4		381	8.30	158	0.060	0.600	0.060	0.008
	14 00	0030	13.5	0.0		379	7.60	179	0.240	0.700	0.050	0.005
	14 00	0035	12.1	0.0		367	7.60	185	0.400	0.800	0.050	0.005
	14 00	0050	10.5	0.0		366	7.40	197	1.460	2.000	0.000	0.010

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L
73/05/02	13 50	0000	0.012	6.5
	13 50	0006	0.015	
	13 50	0015	0.014	
	13 50	0025	0.013	
	13 50	0037	0.012	
	13 50	0051	0.014	
73/08/04	14 35	0000	0.015	4.7
	14 35	0005	0.017	
	14 35	0015	0.014	
	14 35	0020	0.018	
	14 35	0025	0.026	
	14 35	0040	0.022	
	14 35	0055	0.083	
73/10/15	14 00	0000	0.014	3.2
	14 00	0025	0.011	
	14 00	0030	0.013	
	14 00	0035	0.013	
	14 00	0050	0.010	

STORET RETRIEVAL DATE 76/03/30

185302
41 42 04.0 085 02 26.0 3
LAKE JAMES
18151 INDIANA
083291

11EPALES 2111202
0066 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
73/05/02	14 45	0000	12.9		204	480	8.30	183	0.080	0.700	0.130	0.003
	14 45	0006	12.9	10.4		490	8.30	182	0.070	0.600	0.130	0.004
	14 45	0015	12.9	10.6		490	8.30	181	0.070	0.700	0.120	0.004
	14 45	0025	12.6	10.5		495	8.30	180	0.070	0.600	0.120	0.002
	14 45	0035	11.2	10.3		500	8.20	183	0.090	0.600	0.130	0.004
	14 45	0048	9.6	9.5		500	8.20	182	0.110	0.700	0.140	0.008
	14 45	0062	8.4	7.7		500	8.00	186	0.320	0.900	0.110	0.009
73/08/04	15 30	0000	25.7	8.7	108	451	8.40	156	0.070	1.000	0.040	0.004
	15 30	0005	25.1			447						
	15 30	0010	24.6	8.7		440	8.40	157	0.060	0.800	0.040	0.004
	15 30	0015	24.0	8.0		434	8.10	157	0.040	0.800	0.040	0.005
	15 30	0020	18.3	4.3		417	7.40	179	0.060	0.800	0.060	0.006
	15 30	0025	14.0	1.4		375	7.40	182	0.080	0.800	0.090	0.007
	15 30	0030	13.3			366						
	15 30	0040	11.8	1.6		357	7.40	182	0.080	0.800	0.310	0.013
	15 30	0050	10.8			338						
	15 30	0060	8.7			330						
	15 30	0065	8.4	0.8		333	7.30	190	1.220	1.700	0.190	0.123
73/10/15	13 15	0000	17.7	8.0	156	379	8.30	158	0.050	0.800	0.050	0.003
	13 15	0025	16.8	7.4		384	8.20	158	0.050	0.700	0.050	0.003
	13 15	0030	14.4	0.2		376	7.60	177	0.050	0.500	0.040	0.004
	13 15	0035	11.8	0.2		363	7.50	183	0.120	0.600	0.040	0.004
	13 15	0050	8.6	0.0		336	7.50	183	0.300	0.700	0.070	0.005
	13 15	0064	7.1	0.0		346	7.40	196	1.260	2.000	0.100	0.094

STORET RETRIEVAL DATE 76/03/30

185302
41 42 04.0 085 02 26.0 3
LAKE JAMES
18151 INDIANA
083291

11EPALES 2111202
0066 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L
73/05/02	14 45	0000	0.010	5.3
	14 45	0006	0.023	
	14 45	0015	0.020	
	14 45	0025	0.014	
	14 45	0035	0.016	
	14 45	0048	0.019	
	14 45	0062	0.107	
73/08/04	15 30	0000	0.013	4.6
	15 30	0010	0.014	
	15 30	0015	0.014	
	15 30	0020	0.026	
	15 30	0025	0.017	
	15 30	0040	0.018	
	15 30	0065	0.126	
73/10/15	13 15	0000	0.008	4.0
	13 15	0025	0.009	
	13 15	0030	0.013	
	13 15	0035	0.014	
	13 15	0050	0.012	
	13 15	0064	0.122	

STORET RETRIEVAL DATE 76/03/30

185303
41 42 54.0 085 02 31.0 3
LAKE JAMES
18151 INDIANA

083291

11EPALES 2111202
0040 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
73/05/02	15	25 0000	12.9		172	500	8.20	185	0.100	0.800	0.130	0.003
	15	25 0006	12.9	10.2		500	8.20	186	0.080	0.700	0.130	0.005
	15	25 0015	12.9	10.4		500	8.30	186	0.080	0.700	0.130	0.005
	15	25 0025	12.9	10.4		500	8.30	184	0.080	0.600	0.130	0.005
	15	25 0036	10.3	9.8		500	8.10	186	0.120	0.600	0.140	0.011
73/08/04	16	15 0000	25.8	8.6	100	456	8.40	163	0.080	1.000	0.080	0.006
	16	15 0005	24.8	8.8		445	8.40	164	0.040	0.500	0.040	0.012
	16	15 0010	24.7			444						
	16	15 0015	24.3	7.6		438	7.70	173	0.050	0.500	0.050	0.008
	16	15 0020	20.6	4.8		425	7.70	171	0.050	0.500	0.050	0.008
	16	15 0025	15.0	1.3		378	7.40	184	0.070	0.500	0.110	0.010
	16	15 0030	13.6	0.9		372	7.30	186	0.080	0.400	0.400	0.017
	16	15 0040	11.7			353						
	16	15 0050	9.5	0.8		340	7.30	195	0.750	1.000	0.150	0.113
	16	15 0060	8.9			334						
	16	15 0070	8.3			335						
	16	15 0078	8.0	0.0		338	7.40	195	1.100	1.600	0.190	0.217
73/10/13	13	45 0000	18.6	9.0	156	390	8.50	153	0.090	0.800	0.040	0.020
	13	45 0015	18.5	8.6		390	8.40	154	0.070	0.800	0.030	0.020
	13	45 0027	17.2	3.6		389	8.00	158	0.060	0.700	0.030	0.008
	13	45 0033	12.5	0.0		371	7.60	178	0.080	0.700	0.020	0.007
	13	45 0040	10.4	0.0		356	7.50	176	0.200	0.800	0.050	0.007
	13	45 0055	7.8	0.0		338	7.50	181	0.320	1.000	0.040	0.016
	13	45 0081	6.5	0.0		346	7.30	191	1.700	4.600	0.060	0.310

STORET RETRIEVAL DATE 76/03/30

185303
41 42 54.0 085 02 31.0 3
LAKE JAMES
18151 INDIANA
083291

11EPALES 2111202
0040 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L
73/05/02	15 25	0000	0.014	4.9
	15 25	0006	0.017	
	15 25	0015	0.020	
	15 25	0025	0.015	
	15 25	0036	0.015	
73/08/04	16 15	0000	0.016	4.6
	16 15	0005	0.016	
	16 15	0015	0.018	
	16 15	0020	0.020	
	16 15	0025	0.019	
	16 15	0030	0.021	
	16 15	0050	0.123	
	16 15	0078	0.219	
73/10/13	13 45	0000	0.031	5.9
	13 45	0015	0.024	
	13 45	0027	0.018	
	13 45	0033	0.017	
	13 45	0040	0.015	
	13 45	0055	0.023	
	13 45	0081	0.478	

APPENDIX E

TRIBUTARY DATA

STORET RETRIEVAL DATE 76/03/30

1853A1
41 42 00.0 085 02 55.0 4
UNNAMED STREAM
18 7.5 W ANGOLA
O/LAKE JAMES 083291
SEC HWY BRDG NEAR COMMUNITY OF LK JAMES
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/06/09	16 15		0.016	1.000	0.054	0.009	0.020
73/07/15	11 00		0.014	0.980	0.017	0.008	0.010
73/08/12	10 10		0.020	0.660	0.016	0.005K	0.017
73/09/12	17 45		0.011	0.780	0.035	0.007	0.010
73/10/14	17 05		0.012	0.650	0.035	0.007	0.015
73/11/11	11 00		0.019	0.500	0.078	0.005K	0.005K
73/12/08	11 36		0.036	0.500	0.096	0.008	0.015
74/01/06	11 10		0.650	0.500	0.066	0.006	0.015
74/02/24	10 35		0.168	0.900	0.035	0.010	0.025
74/03/10	14 00		0.216	0.600	0.020	0.005K	0.010
74/03/26	10 25		0.208	0.650	0.035	0.005K	0.020
74/04/09	11 50		0.176	0.600	0.025	0.005	0.020
74/05/05	15 20		0.040	0.700	0.020	0.005K	0.025

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/03/30

185381
41 40 55.0 085 01 12.0 4
UNNAMED STREAM
18 7.5 W ANGOLA
T/LAKE JAMES 083291
SEC HWY BRDG NEAR LAKE JAMES GOLF COURSE
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/06/09	16 00		0.570	2.310	0.087	0.008	0.030
73/07/15	10 55		0.390	1.400	0.154	0.007	0.020
73/08/12	10 03		0.320	1.760	0.290	0.005K	0.015
73/09/12	19 35		0.340	0.540	0.009	0.007	0.025
73/10/14	16 55		0.300	0.500	0.033	0.007	0.015
73/11/11	10 35		0.410	0.550	0.048	0.012	0.015
73/12/08	11 27		0.700	0.700	0.062	0.005	0.020
74/01/06	10 30		0.640	0.400	0.060	0.005K	0.010
74/02/10	11 10		0.840	0.800	0.070	0.005K	0.015
74/02/24	10 25		1.800	1.100	0.055	0.010	0.055
74/03/10	14 35		1.680	0.100K	0.035	0.005	0.030
74/03/26	10 55		0.830	0.600	0.040	0.005K	0.010
74/04/09	11 00		0.910	0.800	0.055	0.010	0.020
74/05/05	15 15		0.490	0.800	0.040	0.005	0.035

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/03/30

1853C1
41 02 07.0 085 01 12.0 4
UNNAMED STREAM
18 7.5 W ANGOLA
T/LAKE JAMES 060191
BANK NEAR MOUTH .5 MI N OF GLEN EDEN
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/06/09	15 40		0.014	1.800	0.069	0.100	0.188
73/07/15	10 30		0.021	1.350	0.240	0.071	0.163
73/08/12	09 35		0.029	1.600	0.074	0.035	0.127
73/09/12	19 20		0.010K	1.050	0.031	0.026	0.065
73/10/14	16 45		0.010K	0.800	0.020	0.011	0.040
73/11/11	10 14		0.012	0.500	0.028	0.016	0.025
73/12/08	11 20		0.056	0.400	0.060	0.005K	0.010
74/01/06	10 50		0.640	0.500	0.064	0.005K	0.015
74/03/10	14 20		0.200	0.600	0.020	0.005K	0.010
74/03/26	10 10		0.840	0.500	0.035	0.005K	0.010
74/04/09	10 30		0.028	0.800	0.030	0.015	0.025
74/05/05	14 05		0.480	0.500	0.025	0.005K	0.025

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/03/30

185301
40 43 10.0 085 02 20.0 4
UNNAMED STREAM
18 7.5 W ANGOLA
T/LAKE JAMES 051792
BANK NEAR MOUTH JUST NE OF EAGLE ISLAND
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
73/06/09	16	45	0.014	3.780	0.075	0.009	0.025
73/07/15	11	30	0.010K	1.380	0.056	0.010	0.025
73/08/12	10	30	0.015	0.880	0.026	0.005K	0.020
73/09/12	18	45	0.010K	0.690	0.028	0.006	0.015
73/10/14	17	20	0.010K	0.700	0.031	0.006	0.070
73/11/11			0.010K	0.650	0.044	0.012	0.020
73/12/08	11	45	0.024	0.600	0.100	0.016	0.025
74/01/06	11	40	0.630	0.600	0.072	0.005K	0.015
74/02/10	11	40	1.260	1.000	0.090	0.045	0.065
74/03/10	15	25	0.076	1.100	0.095	0.065	0.110
74/03/26	11	15	0.208	0.600	0.030	0.005	0.015
74/04/09	11	50	0.160	0.700	0.050	0.005	0.020
74/05/05	15	25	0.040	0.600	0.020	0.005K	0.025

K VALUE KNOWN TO BE
LESS THAN INDICATED